STANDARDS AUSTRALIA

Australian Standard

Cross-linked polyethylene (PE-X) pipe for hot and cold water applications

1 SCOPE This Standard specifies requirements for cross-linked polyethylene pipe for use in water supplies, including domestic, industrial, agricultural and other hot and cold water applications. Pipes complying with this Standard shall not be stored or installed in direct sunlight. This Standard applies to pipe with or without integral barrier layers.

NOTES:

1 Cross-linked polyethylene pipe is intended to be used with fittings complying with AS 2537. Jointing cross-linked polyethylene pipe by means of solvent cement is not satisfactory.

2 While this Standard applies to pipes with or without integral barrier layers, the barrier layer is not considered in the pipe performance requirements.

2 REFERENCED DOCUMENTS

The following documents are referred to in this standard:

AS	
1199	Sampling procedures and tables for inspection by attributes
1399	Guide to AS 1199—Sampling procedures and tables for inspection by attributes
1462	Methods of test for unplasticized PVC (UPVC) pipes and fittings
1462.14	Part 14: Method for determination of the light transmission of UPVC pipe
1984	Vernier callipers (metric series)
2102	Micrometer callipers for external measurement (ISO 3611:1978)
2537	Mechanical jointing fittings for use with cross-linked polyethylene (PE-X) pipes for hot and cold water applications
3500	National Plumbing and Drainage Code
3500.0	Part 0: Glossary of terms
3855	Suitability of plumbing and water distribution systems products for contact with potable water
4020*	Products for use in contact with water intended for human consumption with regard to their effect on the quality of water
4131*	PE pipe compounds
AS/NZS	
ISO 9000	Quality management and quality assurance standards
ISO 9000.1	Part 1: Guidelines to selection and use
ISO 9004	Quality management and quality system elements
ISO 9004.1	Part 1: Guidelines
SAA/SANZ	
HB18	Guidelines for third-party certification and accreditation
HB18.44	Guide 44—General rules for ISO or IEC international third-party certification schemes for products

* First published as an Interim Standard.

ISO	
2506	Polyethylene pipes (PE)—Longitudinal reversion—Test methods and specification
DIS 11420	Methods of test for dispersion of additives in polyethylene pipes
ASTM	
D1603	Test method for carbon black in olefin plastics
D3849	Test method for carbon black primary aggregate dimensions from electron microscope image analysis

3 DEFINITIONS For the purpose of this Standard, the definitions given in AS 3500.0 and those below apply.

3.1 Barrier layers—an external layer of material added to the standard pipe to promote existing, or give additional, pipe characteristics.

3.2 Hoop stress—the stress in a pipe or fitting under pressure acting tangentially to the perimeter of a transverse section.

3.3 Hydrostatic design stress (HDS)—hoop stress due to internal hydrostatic pressure that can be applied continuously at a specified temperature. It is obtained by the application of a safety factor to the extrapolated 50-year long-term hydrostatic strength value.

3.4 Lower confidence limit long-term hydrostatic strength (LCL LTHS)—the 97.5% lower confidence limit value of hoop stress, continuously applied at a specified temperature, that the material in pipe form can support for a specified time. This value is calculated using the statistical procedures outlined in Appendix A.

3.5 Minimum required strength (MRS)—the required values of LCL LTHS for the specified temperatures in Table 1 and a time of 50 years.

3.6 Pipe material temperature (PMT)—the average temperature estimated as applying through the full wall thickness.

3.7 Standard dimension ratio (SDR)—the maximum mean outside diameter ($D_{m\ max.}$) divided by the minimum wall thickness ($T_{min.}$).

3.8 Test pressure—the pressure applied internally to pipes and fittings when being tested for strength and watertightness.

3.9 Working pressure—the maximum pressure that can be sustained by the type and class of pipe or fitting for its estimated useful life under the anticipated working conditions.

4 NOTATION The following notation shall apply in this Standard:

DN = nominal size, in millimetres

D_m = mean outside diameter, in millimetres

D_i = mean inside diameter, in millimetres

D_o = outside diameter, including ovality, in millimetres

PN = nominal pressure at 20°C

T = wall thickness, in millimetres

5 HOOP STRESS Cross-linked polyethylene pipe shall be designed for the MRS values given in Table 1 according to the pipe material temperature. The pipe, when tested in accordance with Appendix A shall exhibit MRS values greater than or equal to those given in Table 1. The LCL LTHS values at 50 years shall be calculated in accordance with Appendix A for at least three temperatures (e.g. 20, 60 and 95°C) individually. The LCL LTHS values thus determined must be equal to or greater than the MRS values given in Table 1.

TABLE 1
HOOP STRESS

Pipe material temperature °C	Minimum required strength (MRS) MPa	Hydrostatic design stress (HDS) MPa
20	9.0	6.4
40	7.8	5.9
60	6.6	5.1
80	5.5	4.2
95	4.1	3.2
100	3.6	2.8

NOTES:

1 The hydrostatic design stress has been based upon an extrapolated 50-year MRS, but this should not be taken as the life of the material under service conditions at elevated temperatures. However, on the basis of information from 12 years' evaluation of cross-linked polyethylene, tests have indicated satisfactory performance for eight years while operating continuously at the MRS value and at a temperature of 95°C. The corresponding lifetime at a continuous temperature of 100°C is approximately five years and, at 80°C, 30 years.

2 As hot water systems are not normally designed to operate at boiling point, the stress levels at 100°C have been included for guidance only.

6 CLASSIFICATION Cross-linked polyethylene pipe shall be classified according to nominal pressure (*PN*) at a pipe material temperature of 20°C, as follows:

(a) PN 12.5—maximum continuous working pressure of 1.25 MPa.

(b) PN 16—maximum continuous working pressure of 1.6 MPa.

(c) PN 20—maximum continuous working pressure of 2.0 MPa.

7 WORKING PRESSURE ACCORDING TO TEMPERATURE RATING The working pressure in the pipe shall be as given in Table 2 according to the pipe material temperature.

TABLE 2
PRESSURE DERATING OF PIPES ACCORDING TO PIPE MATERIAL TEMPERATURE (PMT)

PN	Pipe material temperature (PMT)					
	20°C	40°C	60°C	80°C	95°C	100°C
	Working pressure, MPa					
12.5	1.25	1.18	1.02	0.84	0.64	0.56
16	1.60	1.48	1.28	1.05	0.80	0.70
20	2.00	1.87	1.62	1.33	1.02	0.89

8 GENERAL REQUIREMENTS

8.1 Composition

8.1.1 *General* Pipe shall be manufactured only from compounds of polyethylene that enable compliance with the performance requirements of this Standard.

8.1.2 *Additives* In order to achieve stabilization and resistance to embrittlement, the pipe shall contain additives, such as antioxidants and stabilizers. The level of antioxidant in the manufactured pipe must be sufficient to protect it against oxidative ageing and consequent embrittlement during its operating service life.

8.1.3 *Carbon black* Where carbon black is used as an ultraviolet stabilizer pipe extrusion compounds shall contain 2.25 ±0.25% by mass of carbon black, when determined in accordance with ASTM D1603. Other methods of determining the carbon black content may be used, e.g. thermogravimetric analysis, provided that they have been demonstrated to give an accuracy of the same or a higher degree than that in ASTM D1603. In the event of a dispute, the method of ASTM D1603 shall be the referee method. Carbon black shall comply with the following requirements:

(a) Average particle size of 10 to 25 nanometres (nm) when determined in accordance with ASTM D3849.

(b) Maximum volatile content: 2% when determined in accordance with AS 4131.

(c) Maximum toluene extract: 0.1% when determined in accordance with AS 4131.

8.1.4 *Dispersion of additives* Antioxidants, ultraviolet stabilizers and pigments shall be evenly dispersed in the compounds, such that, when tested in accordance with ISO DIS/11420, the arithmetic average of the maximum sizes of pigment agglomerations, bubbles, voids or foreign bodies must not exceed 60 micrometres, corresponding to Grade 3 of ISO DIS/11420. In addition, individual maximum sizes shall not exceed 100 micrometres, corresponding to Grade 5 of ISO DIS/11420.

8.1.5 *Opacity* Pipe may be either translucent or opaque. Pipe claiming to be opaque shall comply with the requirements of Clause 9.6.

8.2 Diameter and wall thickness When measured in accordance with Appendix B, the pipe shall conform to the dimensions given in Table 3.

8.3 Length Unless otherwise specified, pipe shall be supplied in straight lengths of 6 m with a tolerance of +.05, −0 m.

The length of pipe in coils shall be not less than that designated by the manufacturer.

8.4 Freedom from defects

8.4.1 *General* Defects shall not affect the performance or function of the pipe in service.

8.4.2 *Pipes* Pipes shall be free from blisters and heat marks.

8.4.3 *Pipe ends* Pipe ends shall be free from chips and rough edges and shall have sharp edges removed. Pipe ends shall be nominally square.

8.4.4 **Cleanliness** Pipes shall be clean, smoothly cut and free from any manufacturing debris.

NOTE: The defects described in Clauses 8.4.2 and 8.4.4 cannot be completely quantified. Where the presence, size or frequency of any of these are considered to be of concern, arrangements should be made between purchaser/regulatory authority/certifying body (as appropriate) and the manufacturer. This may be achieved by the provision of acceptable reference samples. Where defects are present and product is submitted for acceptance, the manufacturer should be able to demonstrate fitness for purpose.

8.5 Toxicity and effect on water Pipe manufactured to this Standard shall comply with AS 3855 or AS 4020.

8.6 Packaging If the pipe is coiled, the coiling shall be carried out at a temperature that will ensure that the difference between the maximum and minimum external pipe diameters at any cross-section will not exceed 10%.

The minimum internal diameter for a coil of pipe shall be such that kinking of the pipe is prevented.

9 TEST REQUIREMENTS

9.1 Strength characteristics When pipe is tested at 110 ±2°C in accordance with Appendix C, it shall withstand an internal pressure equivalent to a hoop stress of 2.5 MPa for 8760 +50, −0 h.

9.2 Environmental stress cracking resistance When pipe is tested at 95 ±2°C in accordance with Appendix D, it shall withstand a hoop stress of 4.4 MPa for 165 +24, −0 h.

9.3 Pressure test When pipe is tested at 95 ±2°C in accordance with Appendix C, it shall withstand an internal pressure equivalent to a hoop stress of 4.8 MPa and 4.6 MPa, for periods of 1 h and 165 h respectively.

9.4 Degree of cross-linking The degree of cross-linking of the polyethylene shall be determined by measuring the gel content. When determined in accordance with Appendix E, the gel content of the pipe shall achieve the following minimum values:

(a) Peroxide cross-linking 70%.

(b) Silane cross-linking 65%.

(c) Electron beam cross-linking 60%.

(d) AZO cross-linking 60%.

9.5 Reversion test When pipe is tested in accordance with ISO 2506, Method B, at 120 ±2°C the percentage length variation or longitudinal reversion shall not exceed 3.0%.

9.6 Light transmission When opaque pipe is tested in accordance with AS 1462.14, the amount of light transmitted through the pipe wall shall not exceed 0.1%.

10 MARKING All pipes shall be legibly and indelibly marked with letters of minimum height 2.5 mm for pipes up to and including DN 16, 3 mm for pipes up to and including DN 25, and 4 mm for pipes DN 32 and above. The markings shall be reproduced at intervals such that the length of any unmarked pipe shall not exceed 1 m.

The following information shall be marked on the pipe:

(a) The manufacturer's name or registered trademark.

(b) The nominal size of pipe in the form 'DN 25', as appropriate.

(c) Classification, in the form 'PN 20', as appropriate.

(d) The letters 'PE-X'.

(e) Date of manufacture, in the form 941015 (i.e. the 15 October 1994), as appropriate.

(f) The letters 'OP' if the pipe is claimed to be opaque and complies with the requirements of Clause 9.6.

(g) The place of manufacture (manufacturer's code is acceptable), e.g. P1.

Example: The following is an example of the mandatory marking and the order required:

TRADE NAME DN 25 PN 20 PE-X 940515 OP P1

NOTE: Manufacturers making a statement of compliance with this Australian Standard on a product, or on packaging or promotional material related to that product, are advised to ensure that such compliance is capable of being verified. Alternative means for demonstrating compliance with this Standard are given in Appendix F.

TABLE 3

DIMENSIONS OF CROSS-LINKED POLYETHYLENE PIPE

millimetres

Nominal size	Mean outside diameter		Outside diameter inc. ovality		PN 12.5 (SDR 11)				PN 16 (SDR 9)				PN 20 (SDR 7.4)			
	min.	max.	min.	max.	Wall thickness		Mean inside diameter		Wall thickness		Mean inside diameter		Wall thickness		Mean inside diameter	
DN	$D_{m\ min.}$	$D_{m\ max.}$	$D_{o\ min.}$	$D_{o\ max.}$	$T_{min.}$	$T_{max.}$	$D_{i\ min.}$	$D_{i\ max.}$	$T_{min.}$	$T_{max.}$	$D_{i\ min.}$	$D_{i\ max.}$	$T_{min.}$	$T_{max.}$	$D_{i\ min.}$	$D_{i\ max.}$
12	12.0	12.3	11.4	12.6	2.0	2.3	7.4	8.3	2.0	2.3	7.4	8.3	2.0	2.3	7.4	8.3
16	16.0	16.3	15.2	17.1	2.0	2.3	11.4	12.3	2.0	2.3	11.4	12.3	2.2	2.5	11.0	11.9
20	20.0	20.3	19.0	21.3	2.0	2.3	15.4	16.3	2.3	2.6	14.8	15.7	2.8	3.2	13.6	14.7
25	25.0	25.3	23.8	26.6	2.3	2.6	19.8	20.7	2.8	3.2	18.6	19.7	3.5	3.9	17.2	18.3
32	32.0	32.3	30.4	33.9	2.9	3.2	25.6	26.5	3.6	4.0	24.0	25.1	4.4	4.9	22.2	23.5
40	40.0	40.4	38.0	42.4	3.7	4.1	31.8	33.0	4.5	5.0	30.0	31.4	5.5	6.1	27.8	29.4
50	50.0	50.4	47.5	52.9	4.6	5.0	40.0	41.2	5.6	6.2	37.6	39.2	6.9	7.7	34.6	36.6
63	63.0	63.5	59.9	66.7	5.8	6.3	50.4	51.9	7.1	7.9	47.2	49.3	8.6	9.5	44.0	46.3
75	75.0	75.6	71.3	79.4	6.8	7.4	60.2	62.0	8.4	9.3	56.4	58.8	10.3	11.4	52.2	55.0
90	90.0	90.8	85.5	95.3	8.2	8.9	72.2	74.4	10.1	11.2	67.6	70.6	12.3	13.6	62.8	66.2
110	110.0	110.9	104.5	116.4	10.0	10.9	88.2	90.9	12.3	13.6	82.8	86.3	15.1	16.6	76.8	80.7
125	125.0	126.0	118.8	132.3	11.4	12.4	100.2	103.2	14.0	15.4	94.2	98.0	17.1	18.8	87.4	91.8

NOTE: In the interest of serviceability of the pipe, and irrespective of the calculated minimum wall thickness, this Standard does not provide for a wall thickness of less than 2.0 mm.

APPENDIX A

METHOD FOR THE DETERMINATION OF LONG-TERM HYDROSTATIC STRENGTH

(Normative)

A1 SCOPE This Appendix sets out a method for determining the LCL LTHS at 50 years of cross-linked polyethylene (PE-X) pipe.

A2 PRINCIPLE Test pieces, in the form of pipe or an assembly of pipe and fittings at the relevant temperatures, or at temperatures above and below each relevant temperature, are subjected to levels of sustained hydrostatic stress to produce failures of the pipe alone after periods ranging up to more than 10 000 h. The data is extrapolated to determine the failure times at the relevant stresses and temperatures, with reference to the 97.5% lower confidence limits for the results.

A3 APPARATUS The following apparatus is required:

(a) *Pressurizing system* A hydraulic system capable of producing the required test pressure and capable of maintaining an accuracy of ±2%. A hydraulic accumulator or pump may be used for this purpose.

Provision shall be made for one or more connections on the hydraulic system at the one time, for connecting to test specimens. If a test specimen bursts, means shall be provided to ensure there will be no lowering of pressure exceeding the ±2% tolerance allowable on other specimens under test. Each connection shall be capable of being isolated.

(b) *End connections*—fittings that will make a watertight connection to the test specimen and to the pressurizing system. The following three types of fittings are allowed:

(i) Fittings rigidly connected to the test specimen so that the lower end of the test specimen carries the weight of one of the fittings and the thrust of the pressure. See Figure A1(a).

(ii) Caps provided with ring joints sealing onto the external surface of the test specimen and connected to one another by a metal rod allowing some longitudinal movement at the ends of the test specimen. Pressure is applied through one cap end, or through the connecting rod. See Figure A1(b).

(iii) Metal plugs provided with ring joints sealing onto the external surface of the test specimen and connected to one another by a metal rod with a central bore allowing some longitudinal movement at the ends of the test specimen. See Figure A1(c).

(c) *Timing devices*—a timing device on each test station to register the duration of the test on each test specimen until the moment of burst or until the specified time of test has elapsed. This timing device shall monitor and record or stop when the test pressure or test temperature exceeds the specified tolerances.

NOTE: An electric contact pressure gauge is considered a satisfactory apparatus for switching the timing device when used in conjunction with a test gauge.

(d) *Reference pressure device*—a pressure gauge or alternative equipment (e.g. pressure transducer) accurate to ±1% of the true value used for setting or measuring and recording the cut-out tolerances.

(e) *Testing environment*—means for testing the specimens immersed in a water bath in which the water is controlled to within ±2°C of the specified test temperature.

A4 PREPARATION OF TEST SPECIMEN The test specimen shall have a free length (L) between end connections at least equal to three times the outside diameter of the pipe, subject to a minimum of 250 mm.

Before assembly, the test specimen shall have its ends squared and cleaned. It shall have no burrs, notches or other markings which may cause premature bursting.

A5 CONDITIONING OF TEST SPECIMEN Each test specimen shall be conditioned at its test temperature ±2°C for a minimum period of 1 h immediately prior to testing.

If the conditioning is in water, the test specimen shall be filled with water. At the commencement of conditioning, all air shall be released from the test specimen. Conditioning in water may be carried out with the test specimen connected to the test apparatus.

A6 DETERMINATION OF TEST CONDITIONS In order to establish MRS values, as given in Table 1, appropriate test temperatures and pressures are required.

A6.1 Test temperature The test temperatures shall be either those given in Table 1, in which case hydrostatic strength at a certain time shall be calculated by the method given in Paragraph A8, or other test temperature, providing they are suitable for interpolation of the results in accordance with Paragraph A8.4.

A6.2 Test pressure Determine the minimum wall thickness and the mean outside diameter of each test specimen in accordance with Appendix B and calculate the internal hydrostatic pressure to be applied from the following equation:

$$P = \frac{2ST_{\text{min.}}}{D_{\text{m}} - T_{\text{min.}}} \qquad \ldots\ \text{A(1)}$$

where

P = internal hydrostatic pressure to be applied, in megapascals

S = hoop stress (MRS values given in Table 1), in megapascals

$T_{\text{min.}}$ = minimum wall thickness, in millimetres

D_{m} = maximum mean outside diameter, in millimetres

Where a 'restrained-end' type end connection (see Figure A1(b) and (c)), is used for this test, the actual test pressure applied may be 11% lower than the calculated value as described above. Tests using 'free-end' connectors are considered to be the reference test.

NOTE: 'Free-end' connections produce longitudinal tensile stress in addition to hoop and radial stresses in the pipe wall. This does not occur in 'restrained-end' connections (see Figure A1(b) and (c)) where wall stresses act in the hoop and radial directions only. Because of this difference in loading, the equivalent hoop stresses in 'free-end' testing of PE-X pipes are approximately 11% lower than in 'restrained-end' specimens test at the same pressure.

A7 PROCEDURE

(a) Immediately after conditioning, fill the test specimen with distilled water at the test temperature and connect it to the apparatus provided, if not already connected.

(b) Apply the internal hydrostatic pressure, reaching the calculated test pressure within 30 s to 60 s of first admitting pressure, and maintain this with an accuracy of ±2% throughout the test.

(c) Maintain the temperature of the water in contact with the test specimen at the test temperature until failure or the time specified in Table A1 has been reached.

(d) Obtain at least 18 test results at each test temperature for the calculation of the log (time) versus log (stress) regression line with failure point distribution in accordance with Table A1. Include as failures at the time of testing those test pieces that have not failed after being under test for more than 10 000 h if they increase the value of the extrapolated hydrostatic strength.

TABLE A1

MINIMUM FAILURE POINT DISTRIBUTION

Failure time range hours	Minimum data point distribution
100—100	2
100—1000	3
1000—7000	3
> 7000	2
> 10 000	1
Total	11 + 7 others

A8 ASSESSMENT OF RESULTS

A8.1 Notation The following symbols are used:

n = the number of observations;

f_i = the $\log_{10}$ of stresses (in MPa) of observation i; $i = 1, ..., n$

h_i = the $\log_{10}$ of time (in h) of observation i; $i = 1, ..., n$

h_{LTHS} = $\log_{10}$ of the time (in h) of the long-term hydrostatic strength

T_1 = temperature above the interpolated temperature

T_2 = temperature below the interpolated temperature

T_f = the temperature for interpolation

t_v = the Student's t for $v = n - 2$ degrees of freedom, as given in Table A2 which gives the upper 2½% points

σ_{LTHS} = the long-term hydrostatic strength

σ_{LCL} = the lower confidence limit of the long-term hydrostatic strength (LCL LTHS)

$\sigma_{LCL(T)}$ = the lower confidence limit of the long-term hydrostatic strength (LCL LTHS) at a temperature T

A8.2 Least squares Calculations of the long-term hydrostatic strength (LTHS) shall be carried out as follows:

(a) Calculate the arithmetic mean of all f_i and h_i:

$$\bar{f} = \frac{1}{n}\Sigma_{i=1}^{n} f_i \qquad \text{. . . A2}$$

$$\bar{h} = \frac{1}{n}\Sigma_{i=1}^{n} h_i \qquad \text{. . . A3}$$

(b) Calculate the following three quantities:

$$S_{\mathrm{ff}} = \Sigma_{i=1}^{n} f_{\mathrm{i}}^{2} - n(\bar{f})^{2} \qquad \ldots \text{A4}$$

$$S_{\mathrm{hh}} = \Sigma_{i=1}^{n} h_{\mathrm{i}}^{2} - n(\bar{h})^{2} \qquad \ldots \text{A5}$$

$$S_{\mathrm{fh}} = \Sigma_{i=1}^{n} f_{\mathrm{i}} h_{\mathrm{i}} - n\overline{fh} \qquad \ldots \text{A6}$$

(c) The regression equation of log time (h) on log stress (f) is:

$$h = a + bf \qquad \ldots \text{A7}$$

where the constants a and b are calculated as follows:

$$b = \frac{S_{\mathrm{fh}}}{S_{\mathrm{ff}}} \ (< 0) \qquad \ldots \text{A8}$$

$$a = \bar{h} - b\bar{f} \qquad \ldots \text{A9}$$

The slope of the regression line, b, must be less than zero or the results shall be rejected.

(d) To obtain the long-term hydrostatic strength, σ_{LTHS}, rewrite Equation A7 substituting h_{LTHS} for h.

$$f_{\mathrm{LTHS}} = (h_{\mathrm{LTHS}} - a)\frac{1}{b} \qquad \ldots \text{A10}$$

and calculate the following anti-log:

$$\sigma_{\mathrm{LTHS}} = 10^{f_{\mathrm{LTHS}}} \qquad \ldots \text{A11}$$

A8.3 Calculations of the lower confidence limit (LCL) shall be as follows:

(a) Calculate the following quantities

$$S_{\mathrm{r}}^{2} = \frac{1}{n-2}\left(S_{\mathrm{hh}} - \frac{S_{\mathrm{fh}}^{2}}{S_{\mathrm{ff}}}\right) \qquad \ldots \text{A12}$$

$$C = b^{2} - \frac{t_{\mathrm{v}}^{2}\, S_{\mathrm{r}}^{2}}{S_{\mathrm{ff}}} \ (> 0) \qquad \ldots \text{A13}$$

$$D = \frac{b(h_{\mathrm{LTHS}} - \bar{h})}{C} - \frac{t_{\mathrm{v}}\, S_{\mathrm{r}}}{C}\sqrt{\frac{(h_{\mathrm{LTHS}} - \bar{h})^{2}}{S_{\mathrm{ff}}} - \frac{C}{n}} \qquad \ldots \text{A14}$$

$$f_{LCL} = \bar{f} + D \qquad \ldots A15$$

Test results shall be rejected if the quantity C is not greater than zero as it is not possible to calculate the lower confidence limit if this is the case.

(b) Calculate the 97.5% lower confidence limit of the long-term hydrostatic strength (LCL LTHS) by the following anti-log:

$$\sigma_{LCL} = 10^{f_{LCL}} \qquad \ldots A16$$

A8.4 Interpolation If testing has been carried out at temperatures other than those specified in Table 1, providing data at two temperatures, one (T_1) above and one (T_2) below the temperature (T_f) specified, use the following method of interpolation to estimate failure times at the specified temperatures.

Following the calculation procedures outlined in Paragraphs A8.2 and A8.3, calculate the values of σ_{LCL} at each temperature $\sigma_{LCL(T_1)}$ and $\sigma_{LCL(T_2)}$ at the specified time.

Calculate the estimated value of $\sigma_{LCL(T_f)}$ for the specified temperature and time using the following Equation:

$$\sigma_{LCL(T_f)} = \sigma_{LCL(T_1)} + \frac{\sigma_{LCL(T_2)} - \sigma_{LCL(T_1)}}{T_2 - T_1}(T_f - T_1) \qquad \ldots A17$$

A9 TEST REPORT The following information shall be reported:

(a) Pipe dimensions, including minimum wall thickness and mean outside diameter.

(b) The test temperature and pressure.

(c) The date of test completion.

(d) The estimated failure time and lower 97.5% confidence limit of failure time (in h) at each test temperature and required stress at the value.

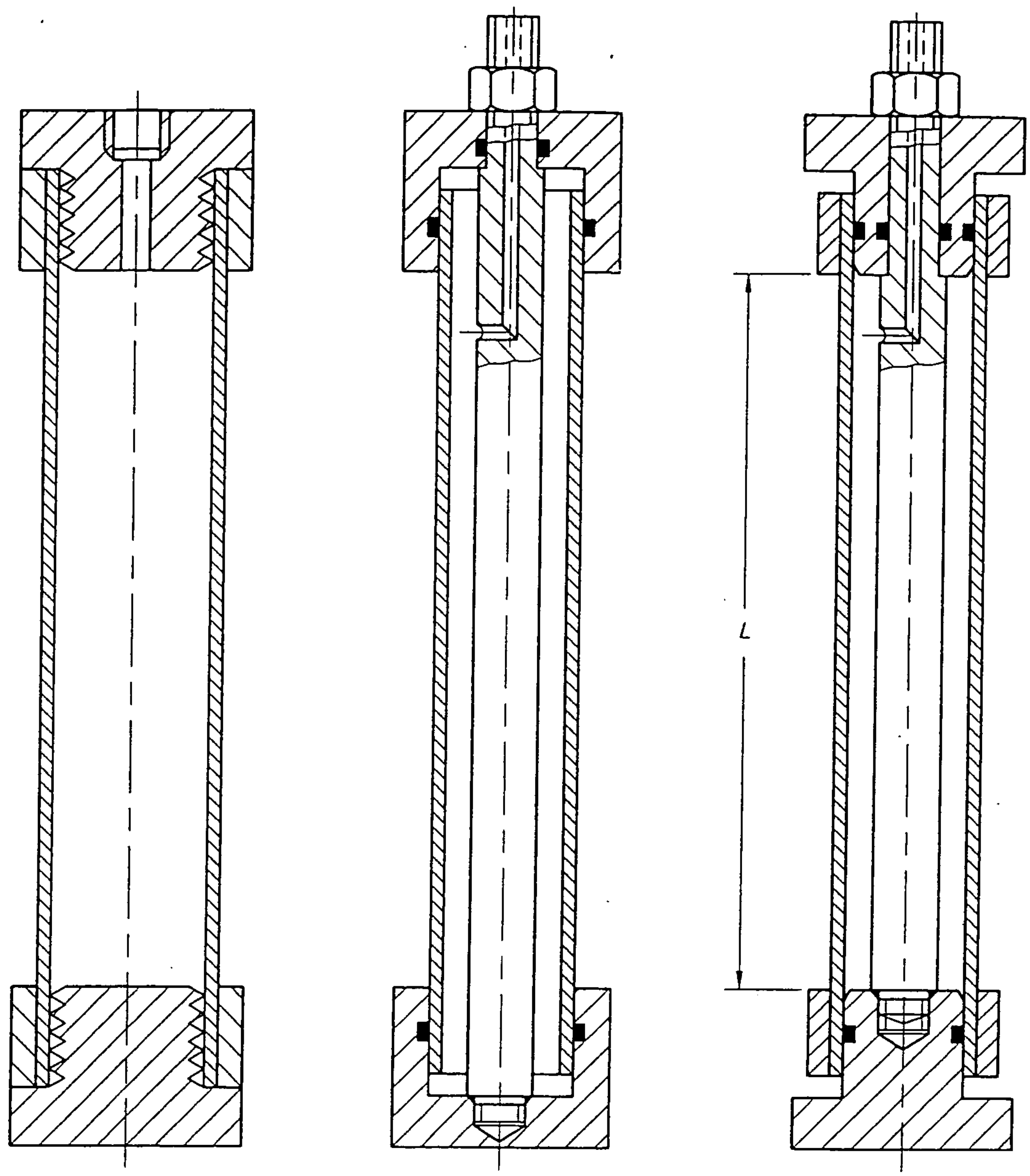
(e) The interpolated values for failure times and lower 97.5% confidence limits at the stress values and temperatures required for compliance with Table 1.

(f) Reference to this test method, i.e. AS 2492, Appendix A.

TABLE A2

PERCENTAGE POINTS OF STUDENT'S t DISTRIBUTION (UPPER 2½% POINTS)

ν	t_ν	ν	t_ν	ν	t_ν
1	12.7062	46	2.0129	91	1.9864
2	4.3027	47	2.0117	92	1.9861
3	3.1824	48	2.0106	93	1.9858
4	2.7764	49	2.0096	94	1.9855
5	2.5706	50	2.0086	95	1.9853
6	2.4469	51	2.0076	96	1.9850
7	2.3646	52	2.0066	97	1.9847
8	2.3060	53	2.0057	98	1.9845
9	2.2622	54	2.0049	99	1.9842
10	2.2281	55	2.0040	100	1.9840
11	2.2010	56	2.0032	102	1.9835
12	2.1788	57	2.0025	104	1.9830
13	2.1604	58	2.0017	106	1.9826
14	2.1448	59	2.0010	108	1.9822
15	2.1315	60	2.0003	110	1.9818
16	2.1199	61	1.9996	112	1.9814
17	2.1098	62	1.9990	114	1.9810
18	2.1009	63	1.9983	116	1.9806
19	2.0930	64	1.9977	118	1.9803
20	2.0860	65	1.9971	120	1.9799
21	2.0796	66	1.9966	122	1.9796
22	2.0739	67	1.9960	124	1.9793
23	2.0687	68	1.9955	126	1.9790
24	2.0639	69	1.9949	128	1.9787
25	2.0595	70	1.9944	130	1.9784
26	2.0555	71	1.9939	132	1.9781
27	2.0518	72	1.9935	134	1.9778
28	2.0484	73	1.9930	136	1.9776
29	2.0452	74	1.9925	438	1.9773
30	2.0423	75	1.9921	140	1.9771
31	2.0395	76	1.9917	142	1.9768
32	2.0369	77	1.9913	144	1.9766
33	2.0345	78	1.9908	146	1.9763
34	2.0322	79	1.9905	148	1.9761
35	2.0301	80	1.9901	150	1.9759
36	2.0281	81	1.9897	200	1.9719
37	2.0262	82	1.9893	300	1.9679
38	2.0244	83	1.9890	400	1.9659
39	2.0227	84	1.9886	500	1.9647
40	2.0211	85	1.9883	600	1.9639
41	2.0195	86	1.9879	700	1.9634
42	2.0181	87	1.9876	800	1.9629
43	2.0167	88	1.9873	900	1.9626
44	2.0154	89	1.9870	1000	1.9623
45	2.0141	90	1.9867	∞	1.9600



(a) Free-end connection

(b) Capped-end connection

(c) Plugged-end connection

FIGURE A1 SUITABLE END CONNECTIONS FOR PRESSURE TESTS

APPENDIX B

METHOD FOR DETERMINING THE DIMENSIONS OF PIPE

(Normative)

B1 SCOPE This Appendix sets out a method for determining the outside diameter and wall thickness of cross-linked polyethylene pipe.

NOTE: Other methods, which can be shown to provide accuracy of the same or a higher degree, may be used.

B2 TEMPERATURE OF MEASUREMENT Field measurements may be taken at ambient temperature and dimensions adjusted to equivalent dimensions at 20°C. The coefficient of thermal expansion of cross-linked polyethylene pipe is taken as 17×10^{-5}/°C. For reference purposes only, all measurements shall be taken at 20 ±2°C.

B3 DETERMINATION OF OUTSIDE DIAMETER

B3.1 Apparatus Micrometer complying with AS 2102 or vernier callipers complying with AS 1984.

B3.2 Procedure

B3.2.1 *Maximum and minimum outside diameters including ovality* The procedure shall be as follows:

(a) Using the micrometer or vernier callipers, take a continuous series of diameter measurements on the same cross-section at right angles to the axis of the pipe.

(b) Determine and record the maximum and minimum outside diameter obtained. Values shall be rounded off to the nearest 0.1 mm with values ending in 0.05 being rounded up.

B3.2.2 *Mean outside diameter* Calculate and record the mean of the two measurements determined in Paragraph B4.2.1(b) or the direct measurement of mean outside diameter made using the diameter tape.

B4 DETERMINATION OF WALL THICKNESS

B4.1 Apparatus External micrometer having a fixed spherical anvil of 3 mm nominal radius and providing an accuracy not less than that specified in the relevant Clauses of AS 2102.

B4.2 Procedure The procedure for determining maximum and minimum wall thicknesses ($T_{max.}$ and $T_{min.}$) shall be as follows:

(a) Using the micrometer, take a series of wall thickness measurements around the circumference at right angles to the axis of the pipe.

(b) Determine and record the maximum and minimum wall thicknesses. Values shall be rounded off to the nearest 0.1 mm with values ending in 0.05 being rounded up.

B5 REPORT The following information shall be reported.

(a) The class and nominal size of the pipe.

(b) Form of apparatus used.

(c) Maximum outside diameter, including ovality.

(d) Minimum outside diameter, including ovality.

(e) Mean outside diameter.

(f) Maximum wall thickness.

(g) Minimum wall thickness.

(h) Reference to this Australian Standard, i.e. AS 2492, Appendix B.

APPENDIX C

METHOD FOR DETERMINING STRENGTH CHARACTERISTICS AND PRESSURE RESISTANCE OF PIPES

(Normative)

C1 SCOPE This Appendix sets out the method for determining the strength characteristics and pressure resistance of cross-linked polyethylene (PE-X) pipe.

C2 PRINCIPLE The pipe is subjected to a calculated test pressure equivalent to a hoop stress of 2.5 MPa for 8760 +50, −0 h at 110 ±2°C, and calculated test pressures equivalent to hoop stresses of 4.8 MPa and 4.6 MPa for periods of 1 h +15, −0 min. and 165 h +24, −0 h, respectively, at 95 ±2°C.

C3 APPARATUS The apparatus described in Appendix A, Paragraph A3, shall be used.

C4 PREPARATION OF TEST SPECIMEN The test specimen shall have a free length (L) between end connections at least equal to 3 times the outside diameter of the pipe, subject to a minimum of 250 mm.

Before assembly, the test specimen shall have its ends squared and cleaned. It shall have no burrs, notches or other markings which may cause premature bursting.

C5 CONDITIONING OF TEST SPECIMEN Each test specimen shall be conditioned at its test temperature ±2°C for a minimum period of 1 h immediately prior to testing.

If the conditioning is in water, the test specimen shall be filled with water. At the commencement of conditioning, all air shall be released from the test specimen. Conditioning in water may be carried out with the test specimen connected to the test apparatus.

C6 PROCEDURE The procedure shall be as follows:

(a) Determine the minimum wall thickness and the mean outside diameter of the test specimen in accordance with Appendix B and the internal hydrostatic pressure to be applied calculated from the following formula:

$$P = \frac{2ST_{\text{min.}}}{D_{\text{m}} - T_{\text{min.}}}$$

where

P = internal hydrostatic pressure (to be applied), in megapascals

S = hoop stress of 2.5 MPa, 4.6 MPa or 4.8 MPa, as applicable

$T_{\text{min.}}$ = minimum wall thickness, in millimetres

D_{m} = mean outside diameter, in millimetres

Where a 'restrained-end' type end connection (see Figure A1(b) and (c)), is used for this test, the actual test pressure applied may be 11% lower than the calculated value, as described above. Tests using 'free-end' connectors are considered to be the reference test.

NOTE: 'Free-end' connections produce longitudinal tensile stress in addition to hoop and radial stresses in the pipe wall. This does not occur in 'restrained-end' connections (see Figure A1(b) and (c)) where wall stresses act in the hoop and radial directions only. Because of this difference in loading the equivalent hoop stresses in 'free-end' testing of PE-X pipes are approximately 11% lower than in 'restrained-end' specimens tested at the same pressure.

(b) Fill the test specimen with distilled water and connect it to the apparatus provided. It should be ensured that all air is released from the system.

(c) Apply the internal hydrostatic pressure, reaching the calculated test pressure within 30 s to 60 s of first admitting pressure, and maintain this with an accuracy of ±2% throughout the test.

(d) Maintain the temperature of the air in contact with the test specimen at the test temperature for the specified time.

C7 REPORT The following information shall be reported:

(a) Pipe dimensions, including minimum wall thickness and mean outside diameter.

(b) Internal hydrostatic pressure applied to each test specimen and the duration and temperature of the test.

(c) Failure of a test specimen to complete the test and, in the event of this occurring, the time to failure. Failure is defined as leaking, weeping or rupturing of the test specimen.

(d) Reference to this test method, i.e. AS 2492, Appendix C.

APPENDIX D
METHOD FOR DETERMINING ENVIRONMENTAL STRESS CRACKING RESISTANCE
(Normative)

D1 SCOPE This Appendix sets out the method for determining the environmental stress cracking resistance of cross-linked polyethylene pipe.

D2 PRINCIPLE The pipe is subjected to an internal pressure equivalent to a hoop stress of 4.4 MPa for 165 +24, −0 h at 95 ±2°C, while exposed to a surface active compound.

D3 APPARATUS The apparatus as specified in Appendix C is required as well as the following:

(a) *Constant temperature bath* A water bath equipped with agitator and specimen manifold with individual valves for specimens, and equipment capable of maintaining a temperature of 95 ±2°C.

(b) *Surface active compound* A non-ionic hydroxyephylation product should be added to the water to give a concentration of 5% surface-active compound (*v*/*v*).

D4 PREPARATION OF TEST SPECIMENS Each test specimen shall be a piece of pipe with a free length (L) between end connections equal to at least 3 times the outside diameter of the pipe subject to a minimum of 250 mm.

Before testing, each test specimen shall have its ends squared and cleaned. It shall not have any burrs, notches or other markings which may cause premature failure.

D5 CONDITIONING OF TEST SPECIMENS At the commencement of conditioning, each test specimen shall be filled with 5% of a surface-active compound from the constant temperature bath. It should be ensured that all air is released from the system. Conditioning may be carried out with the test specimens connected to the test apparatus.

Each test specimen shall be conditioned at 95 ±2°C for a period of not less than 1 h in the constant temperature bath, immediately prior to testing.

D6 PROCEDURE The procedure shall be as follows:

(a) Determine the minimum wall thickness and the mean outside diameter of each test specimen in accordance with the method described in Appendix B, and the internal hydrostatic pressure to be applied calculated from the following formula:

$$P = \frac{2S\,T_{\text{min.}}}{D_{\text{m}} - T_{\text{min.}}}$$

where

P = internal hydrostatic pressure (to be applied), in megapascals

S = hoop stress of 4.4 MPa

$T_{\text{min.}}$ = minimum wall thickness, in millimetres

D_{m} = mean outside diameter, in millimetres

Alternatively, for production control purposes, the values for minimum mean outside diameter ($D_{m\ min.}$) and maximum wall thickness ($T_{max.}$) from Table 3 may be used to calculate the test pressure.

(b) Condition each test specimen in accordance with Paragraph D5.

(c) Connect a test specimen to the apparatus provided, if not already connected and ensure that all air is excluded.

(d) Apply the internal hydrostatic pressure, reaching the calculated test pressure within 30 s to 60 s of first admitting pressure, and maintain this with an accuracy of ±2% throughout the test.

(e) Maintain the temperature of the test environment in contact with the test specimen at 95 ±2°C throughout the test for 165 +24, −0 h.

D7 REPORT The following information shall be reported:

(a) Pipe dimensions, including minimum wall thickness and mean outside diameter.

(b) Internal hydrostatic pressure applied to each test specimen.

(c) Failure of a test specimen to complete the test and, in the event of this occurring, the time to failure. Failure is defined as leaking, weeping or rupturing of the test specimen.

(d) Reference to this test method, i.e. AS 2492, Appendix D.

APPENDIX E

ESTIMATION OF THE DEGREE OF CROSS-LINKING BY DETERMINATION OF THE GEL CONTENT

(Normative)

E1 SCOPE This Appendix sets out the method for the assessment of the degree of cross-linking of cross-linked polyethylene (PE-X) pipes by the determination of the gel content by solvent extraction.

E2 PRINCIPLE Measurement of the mass of insoluble material after immersion of the test piece in a specific solvent for a specified period of time will give an indication of the degree of cross-linking achieved.

The degree of cross-linking is expressed as the percentage by mass of insoluble material.

E3 APPARATUS The apparatus required shall be as follows:

(a) *Hot plate*—with sufficient heating capacity to boil xylene (boiling range 130°C to 140°C).

(b) *Lathe*—with automatic feed for machining the test piece or, alternatively, a microtome.

(c) *Reflux condenser*—of the general type as illustrated in Figure E1.

(d) *Round-bottom flask*—of at least 500 ml capacity. (A 2000 ml flask is suitable for up to six determinations at one time).

(e) *Scales*—with an accuracy of 1 mg.

(f) *Vacuum oven*—or alternatively an oven with forced ventilation and extraction facility.

(g) *Wire cage*—made of 125 μm mesh brass or stainless steel for containing the test piece.

E4 SOLVENT Analytically pure xylene, to which 1% antioxidant [(2,2-methylene-bis(4-methyl-6-tert-butylphenol)] has been added.

> WARNING: XYLENE IS A TOXIC AND FLAMMABLE SOLVENT AND AS SUCH SHOULD BE HANDLED CAREFULLY. EXPOSE ONLY IN A VENTILATED HOOD. CHECK THE EFFECTIVENESS OF THE HOOD BEFORE STARTING THE TESTS. DO NOT INHALE THE VAPOUR. EXCESSIVE INHALATION OF THE VAPOUR MAY CAUSE DIZZINESS, HEADACHE, OR BOTH. IN THE EVENT OF EXCESSIVE VAPOUR INHALATION, SEEK FRESH, CLEAN AIR.

E5 TEST PIECES Shave at least three thin ring test pieces, between 0.1 mm and 0.2 mm, from the end of the pipe to include the full wall thickness and circumference.

NOTE: It is recommended that a lathe is used to machine the test pieces. Alternatively, a microtome may be used.

E6 PROCEDURE The procedure shall be as follows:

(a) Weigh the wire mesh cage and lid to an accuracy of 1 mg (mass M_1).

(b) Place the test piece in the cage and weigh the case, lid and test piece together to an accuracy of 1 mg (mass M_2).

(c) Place the cage and test specimen in the flask and ensure that there is sufficient xylene solution to ensure total immersion.

(d) Boil vigorously to ensure good agitation for 8 h ±5 min.

(e) Remove the cage and residue from the boiling solution and dry with a cloth.

(f) Place in a forced-ventilation oven and dry for 3 h at 140 ±2°C, or in a vacuum oven, and dry for 3 h at 140 ±2°C under vacuum of at least 85 kPa.

(g) Allow cooling to ambient temperature and weigh cage, lid and residue to an accuracy of 1 mg (mass M_3).

(h) Repeat the above procedure for two more specimens.

E7 CALCULATIONS Calculate results as follows:

(a) Calculate the individual degree of cross-linking (g) of each test piece as a percentage by mass of insoluble material using the following equation:

$$g = \frac{m_3 - m_1}{m_2 - m_1} \times 100 \qquad \ldots \text{E7.1}$$

where

g = the degree of cross-linking expressed as a percentage

m_3 = the weight of the residue, cage and lid, in milligrams

m_1 = the weight of the cage and lid, in milligrams

m_2 = the weight of the original test piece, cage and lid, in milligrams

Express the result to the nearest whole number.

(b) Calculate the average degree of cross-linking (G) from the individual results, using the following equation:

$$G = \frac{g_1 + g_2 + g_3}{3} \qquad \ldots \text{E7.2}$$

where

g_1, g_2 and g_3 are individual specimen results.

E8 TEST REPORT The following information shall be reported:

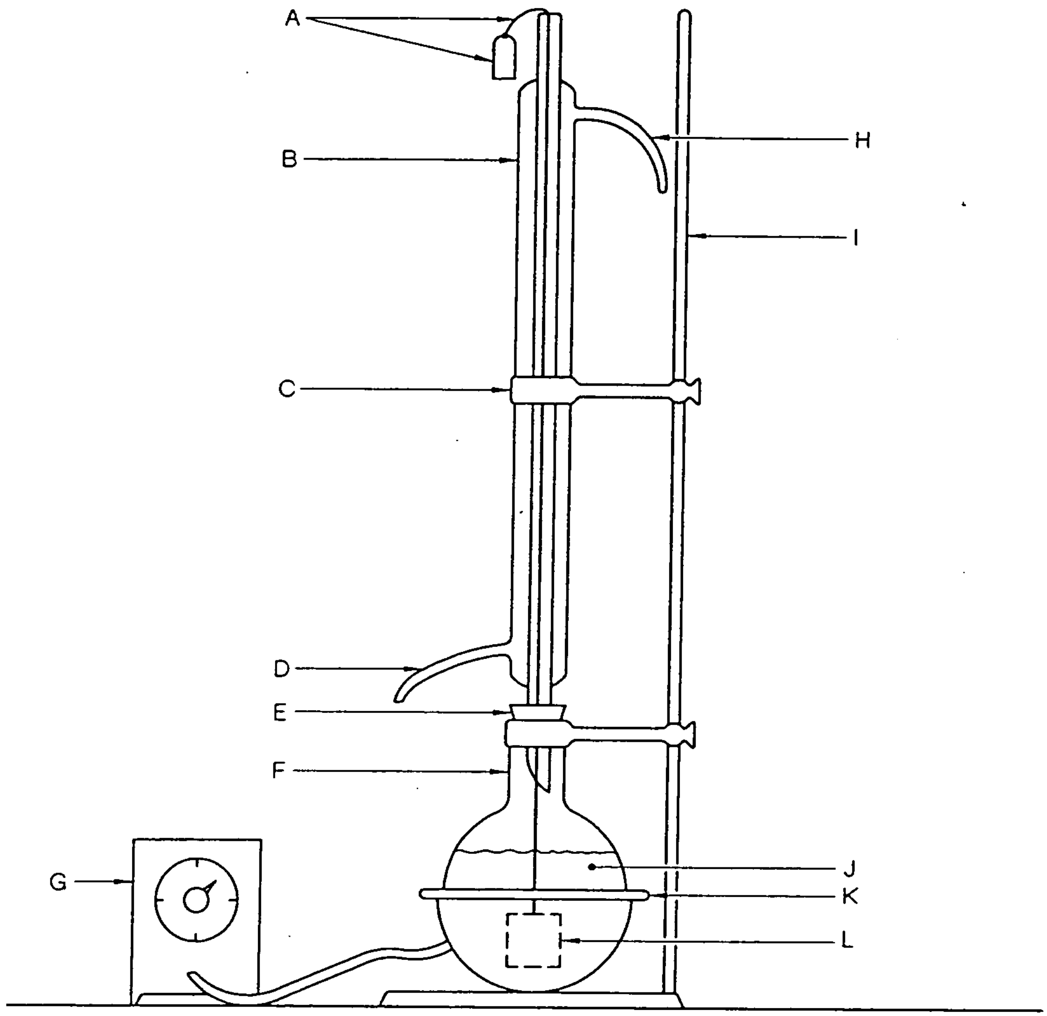
(a) Identification of the test pieces.

(b) The degree of cross-linking (Equation E7.1) for each piece and the average degree of cross-linking (Equation E7.2).

(c) Details of any variation in the specified procedure and of any abnormal behaviour observed during the test.

(d) Date of test.

(e) Reference to this test method, i.e. AS 2492, Appendix E.



LEGEND:
A Identification tag and fine wire attached to cage
B Reflux condensor
C Ring stand clamp
D Water inlet
E Ground-glass or cork joint
F Large-mouth round-bottom flask
G Variable transformer
H Water outlet
I Ring stand
J Xylene
K Heating plate
L 125 μm mesh wire cage containing the specimen

FIGURE E1 REFLUX CONDENSER

APPENDIX F

MEANS FOR DEMONSTRATING COMPLIANCE WITH THIS STANDARD

(Informative)

F1 SCOPE This Appendix sets out the following different means by which compliance with this Standard can be demonstrated by the manufacturer or supplier:

(a) Assessment by means of statistical sampling.

(b) The use of a product certification scheme.

(c) Assurance using the acceptability of the supplier's quality system.

(d) Other such means proposed by the manufacturer or supplier and acceptable to the customer.

F2 STATISTICAL SAMPLING Statistical sampling is a procedure which enables decisions to be made about the quality of batches of items after inspecting or testing only a portion of those items. This procedure will only be valid if the sampling plan has been determined on a statistical basis and the following requirements are met:

(a) The sample must be drawn randomly from a population of product of known history. The history must enable verification that the product was made from known materials at essentially the same time by essentially the same processes and under essentially the same system of control.

(b) For each different situation, a suitable sampling plan needs to be defined. A sampling plan for one manufacturer of given capability and product throughput may not be relevant to another manufacturer producing the same items.

In order for statistical sampling to be meaningful to the customer, the manufacturer or supplier needs to demonstrate how the above conditions have been satisfied. Sampling and the establishment of a sampling plan should be carried out in accordance with AS 1199, guidance to which is given in AS 1399.

F3 PRODUCT CERTIFICATION The purpose of product certification is to provide independent assurance of the claim by the manufacturer that products comply with the stated Australian or international Standard.

The certification scheme should meet the criteria of an ISO Type 5 scheme as specified by SAA HB18.44 in that, as well as full type testing from independently sampled production and subsequent verification of conformance, it requires the manufacturer to maintain an effective quality plan to control production to ensure conformance with the relevant Standard.

The certification scheme serves to indicate that the products consistently conform to the requirements of the Standard.

F4 SUPPLIER'S QUALITY SYSTEM Where the manufacturer or supplier can demonstrate an audited and registered quality management system complying with the requirements of the appropriate or stipulated Australian or international Standard for supplier's quality systems, this may provide the necessary confidence that the specified requirements will be met. The quality assurance requirements need to be agreed between the customer and supplier and should include a quality or inspection and test plan to ensure product conformity.

Guidance in determining the appropriate quality management system is given in AS/NZS ISO 9000.1:1994 and AS/NZS ISO 9004.1:1994.

F5 OTHER MEANS OF ASSESSMENT If the above methods are considered inappropriate, determination of compliance with the requirements of this Standard may be assessed by being based on the results of testing coupled with the manufacturer's guarantee of product conformance.

Irrespective of acceptable quality levels (AQLs) or test frequencies, the responsibility remains with the manufacturer or supplier to supply products that conform with the full requirements of the Standard.

STANDARDS AUSTRALIA

Standards Australia is an independent not-for-profit organization, established in 1922. It operates formally under a Royal Charter as the Standards Association of Australia and has recognition as the peak Standards body in Australia through a Memorandum of Understanding with the Commonwealth Government. The essence of its operation is to bring together individuals and organizations committed to a common objective—to establish Australian Standards as national benchmarks for products and services so as to enhance quality of life and industry efficiency.

AUSTRALIAN STANDARDS

Australian Standards are prepared by committees made up of experts from industry, governments, user groups and other sectors. The requirements or recommendations contained in published Standards are a consensus of the views of representative interests and also take account of comments received from other sources. They reflect latest scientific and industry experience. Australian Standards are kept under continuous review after publication and are updated regularly to take account of changing technology.

INTERNATIONAL INVOLVEMENT

Standards Australia has an important role internationally. It is responsible for ensuring that the Australian viewpoint is considered in the formulation of International Standards and that latest international experience is incorporated in Australian Standards. This role is vital in assisting Australian industry to compete in international markets. Standards Australia is the national member of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

MEMBERSHIP AND INFORMATION

A comprehensive range of services is provided to subscribing members of Standards Australia. Up-to-date information on latest local and international developments in standardization, priority access to publications, and credit facilities are some of these services. Standards Australia's large Information Centres in Sydney and Melbourne also provide reference access to Australian and international Standards as well as those applicable in overseas markets.

Enquiries about subscribing membership and the work of Standards Australia are welcomed at the Head Office or any State office. A Catalogue of Australian Standards is also available at these offices.